5 GALAXIES

Introduction

Galaxy is a gravitationally bound vast system which consists of billions of stars nebulae, dusts, gases, dark matter, dark energy etc.

Galaxies are considered to be fundamental building blocks of our universe. It has been calculated that there are about 125 billion galaxies in the universe. Galaxies occupy only a small portion of the universe, remaining are spaces between galaxies. The size of a galaxy in the visible light is about 20 kpc in diameter, actually it spreads over very much larger than this. it can be seen by a radio or X-ray telescopes. Most of the visible part of the galaxy is contributed by stars. The number of stars in galaxies varies considerably. For instance in some giant galaxies there are about trillion (10^{12}) stars where as in small galaxies such as Leo I there are about a few hundred thousand. Milky way, Andromeda, Large magellanic cloud, Hubble, Ring tail, Codes, etc. are some of the galaxies.

Galaxy types

Galaxies can be broadly classified into five categories depending upon their shapes.

(i) Spiral galaxies

Spiral galaxies appear as flat white discs with yellowish bulges at their centres. The disc regions are occupied by dust and cool gas, interspersed with hotter ionised gas. Their most obvious character is the spiral arms. Example Milky way galaxy. We belong to this galaxy. It is estimated that there are 20,000 crores stars in it. Diameter of the disc of this galaxy is 10^5 ly. Our Sun is at a distance of 26,000 ly from the centre of milky way.

Figure 5.1: Spiral galaxies

(ii) Elliptical galaxies

Elliptical galaxies are redder and seem to be in spherical in shape with a bulge at the centre or elliptical. They contain far less cool gas and dust but very much hot ionised gas comparing to spiral galaxies. Example: Andromeda galaxy. This is the galaxy nearest to ours. It is estimated there are 40,000 corre stars in it.

Figure 5.2: Elliptical galaxies

(iii) Irregular galaxies

Galaxies that appear neither disc like nor rounded are called irregular galaxies.

Example: Large magellanic clouds.

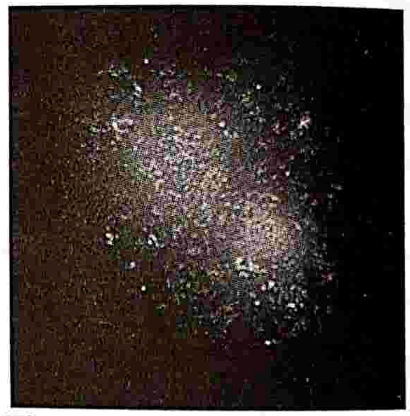

Figure 5.3: Irregular galaxies

(iv) Barred spiral galaxies

Galaxies that exhibit a straight bar of stars that cuts across the centre with spiral arms curling away from the ends of the bars are called barred spiral galaxies.

Example: Tadpole galaxy

Figure 5.4: Barred spiral galaxies

(v) Lenticular galaxies

Galaxies that possess discs but not having spiral arms and they seem to be look like lens -shaped thus called lenticular (lens-shape) galaxies.

Example: Cart wheel galaxy.

The above classification is done by taking shapes of galaxies into account. This classification can further be subdivided by taking their brightness, the tightness of the spiral arms etc. into account.

Figure 5.5: Lenticular galaxies

Galaxy structure (spiral)

Spiral galaxies have three components. They are (i) thin disc, (ii) central bulge and (iii) the halo. Both the centre bulge and the halo together is called spheroidal component.

The thin disc of spiral galaxy extending outward from the central bulge. In the milkyway galaxy thin disc extend 50,000 ly from the centre. The disc area of all spirals contains a mixture of gas and dust called interstellar medium, but the amounts and proportions of the gas whether atomic, ionised or molecular will be different from galaxy to galaxy.

The central bulge merges smoothly into the halo, which can extend to a radius in excess of 1,00,000 ly. There is no clear boundaries for bulge and halo. Stars up to 1,00,000 ly are considered to be bulge stars and those beyond this radius are the members of the halo.

Spiral galaxies have relatively less light intensity than those of elliptical galaxies. Moreover the mass of spiral galaxies is also less than that of elliptical. Spiral galaxies have masses in the range 10^9-$10^{12} M_\odot$. It is found that 70% of spiral galaxies are barred spiral galaxies. The particular structure (bars) plays an important role in the morphology of these galaxies. The bars of the galaxy help to flow gases to the centre of the galaxy thereby setting up a situation to form new stars. As a result of this the centre bulge expands and change the shape of the galaxy.

In spiral galaxy stars are youngsters where as in elliptical stars old aged. The main reason for this is that the amount of gases is more in spherical galaxies. The amount of gases increases the possibility of formation of new stars is also increased. As gases are accumulated in spiral arms more number of new stars are formed in spiral arms. Thus spiral arms glows with much light intensity and appeared to be blue in colour. The old aged stars can also be found in spiral galaxies but they are at the middle of the bulge. The speed of revolution of old aged stars are more than that of youngster stars.

Stellar populations

We found that spiral galaxies have discs with central bulges and spiral arms. Study on aged stars in the galaxies revealed that depending upon the ages of stars disc can be divided into two layers. More gases and dust particles are accumulated at the middle layer disc. This is called thin disc. Star formation is more in this disc. The outer layer disc (bulge region) is called thick

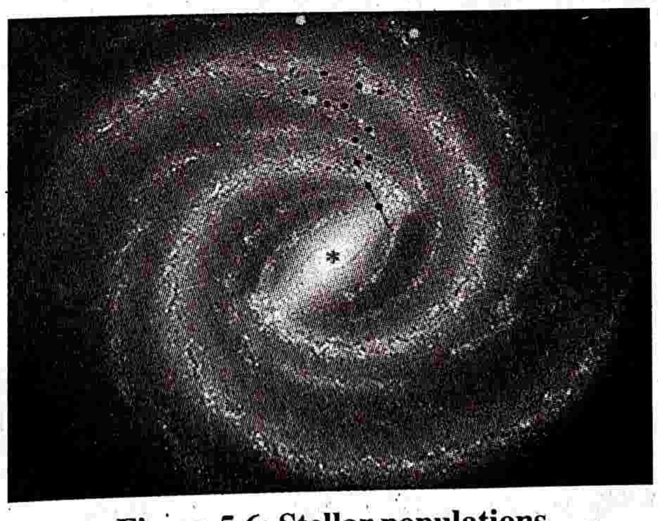

Figure 5.6: Stellar populations

disc. This disc consists of aged stars. The thin discs are at a distance of 100 pc to 325 pc from the galactic plane, where as thick discs spread over a distance of about 1500 pc.

The stars within a spiral galaxy can be classified into two by where they reside. They are population I and population II stars.

The stars in the thin discs are called population I stars. The stars in the thick disc (bulge region) are called population II stars.

Distinction between population I and II stars

1. Population I stars are young, hot and blue in colour where as population II stars are old, red giant stars and orange in colour.
2. The total mass of the population I stars about 15-30 times greater than the total mass of population II stars.

   The total mass of population II stars is about $2\times 10^9 - 4\times 10^9 M_{\odot}$.
3. 2% of the total mass of population I stars are metals (elements having atomic mass greater than that of helium's), whereas in the case of populations II stars only 0.1% of the total mass are metals.
4. The amount of light emitted by population I stars is 90 times greater than that emitted by population II stars.

Hubble classification of galaxies

The American astronomer Edwin Hubble classified galaxies on the basis of their shapes, central bulges, tightness of spiral arms and flatness called Hubble classification.

A galaxy is classified by assigning an upper case letter or letters followed either by a number or by lower case letter or letters. This classification identifies the morphology of the galaxy.

The upper case letter indicates the shape of the galaxy, the number indicates the flatness of the galaxy and the lower case letter or letters indicate the central bulge and tightness of spiral arms of the galaxy.

A spiral galaxy is represented by the letter S. If it is an ordinary spiral it is represented SA and SB represents barred spiral galaxy. It is then followed by a lower case letter a, b, c or d. If a galaxy has a large bulge and tightly wound arms it is assigned the lower case letter a. Altogether it is represented by SAa or SBa. The only difference between these two is that SAa has no bars but SBa has bars. As we go form a to d the central bulge and tightness go on decreasing. SBc is a barred spiral arms with small bulge and loosly wound spiral arms.

An elliptical galaxy is represented by the upper case letter E. This will be followed by a number 0, 1, 2.... etc. The number indicates the flatness of the galaxy. The larger the number the more flatter the galaxy. For example an EO galaxy is round and E8 galaxy is very elongated.

Galaxies neither belong to spiral nor belong to elliptical are called lenticular galaxies. A lenticular galaxy is classified as SO (both upper case). SAO is an ordinary lenticular galaxy where as SBO is a barred lenticular galaxy. In addition for galaxies intermediate between SA and SB is classified as SAB.

We have classified three types of galaxies spiral, elliptical and lenticular galaxies. Galaxies which do not fall into any of above three classification included in Pec or Irr. Pecs is the classification for peculiar galaxies which have a distorted form. Galaxies which have irregular morphology are classified as Irr. This can further be classified into two. IA and IB. IA is the irregular ordinary and IB is the barred irregular galaxy.

The Hubble classification system can be represented by a diagram as shown in figure below.

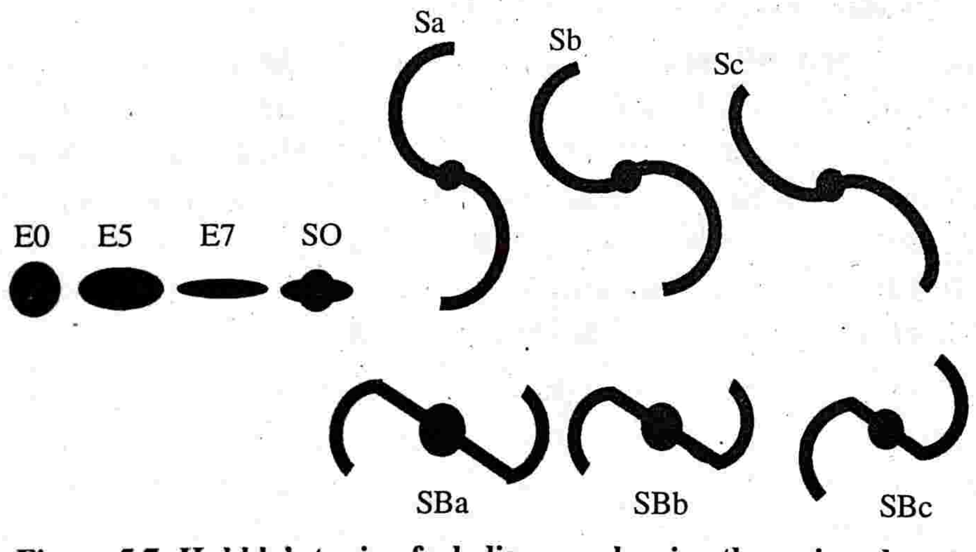

Figure 5.7: Hubble's tuning fork diagram showing the main galaxy types

Observing galaxies

All of us have seen images of galaxies in books and astronomical magazines. The images are highlighted in multicolours and seems to be highly spectacular. Before going to see galaxies, we expect dazzling images of galaxies. In reality contrary to our expectation, we can see galaxies as a pale tiny blob. We can see 9 galaxies with naked eye, binoculars or telescopes. The right location and dark sky are essential requirements to see a galaxy with naked eye. The seen galaxies will be faint and indistinct. The edge of the Milky way galaxy, M31 in Andromeda galaxy, M33 is in

Triangulum galaxy, the sides of Large magellnic cloud etc. can be seen with naked eye.

To see the real structure of galaxies we need largest telescopes and the darkest possible skies. Dark skies and a binoculars enable us to see several other galaxies. If we have a telescope the number of galaxies that can be seen will be increased considerably.

Usually galaxies with magnitude up to 8 can be seen with naked eyes. To see a galaxy of magnitude greater than 13, we require a telescope of aperture 15cm. A telescope of aperture 30cm enables us to see galaxies of magnitude 14.5. However do not expect that all parts of galaxies would be seen with these aids. In some cases only the brightest part of a galaxy will be visible, its core and spiral arms are invisible.

To trace the finer details of spiral arms of galaxies, and to locate the bulge area, faint halo etc. we need a telescope of large aperture about 2m. If our aim is just to locate a galaxy binocular or small aperture telescopes will do . If we locate a galaxy by a binocular or a naked eye there is an amazing thing behind this. That is the light that is interring our eye may have begun their journey over 100 million years ago, then there is a plethora of galaxies awaiting us.

Depending upon the brightness (magnitude) and the area of the sky the galaxy spans the visibility of the galaxy with binoculars is divided into three. They are designated as easy, moderate and difficult. **A galaxy that may be bright with magnitude 8 under normal circumstance would be visible by binoculars is designated as easy. If the galaxy of magnitude 8 covers a larger area of sky will be difficult to observe is designated as moderate. If it is not possible or very difficult to observe the galaxy is designated as difficult.**

To locate or see distant galaxies binoculars are better aids than telescopes. This is because binoculars give 3D images where as telescopes give flat images. For example to see Andromeda galaxy we require a binocular with specification 7 × 50 (7 by 50). The first number gives the magnification of the image with respect to unaided eye. The second number gives the diameter of the lens (aperture) in millimetre. There are large number of binoculars available in the market such as 7 × 50, 10 × 60, 15 ×70, 25 × 100 etc.

Astronomical catalogue

A list of objects is called as catalogue. A list of astronomical objects is called astronomical catalogue. The objects may be planetary nebulae, stars, clusters of stars, galactic clusters, globular clusters, galaxies etc. There are several types of catalogues. Here we introduce only three among them. They are Messier (French astronomer Charles Messier) catalogue, new general catalogue (NGC) and Caldwell catalogue.

The Messier catalogue consists of 110 astronomical objects where as NGC consists of 7840 astronomical objects and Caldwell contains 109 astronomical objects. For example M31. it is an astronomical object occupying 31st position in the Messier catalogue. This object occupying the 224th position of new general catalogue hence it is also named as NGC 224. This is actually a galaxy in the andromeda this is also called as Andromeda galaxy.

Note: Caldwell catalogue was compiled by Patrick Moore (Surname Caldwell) as a complement to Messier catalogue.

Finally we discuss some examples of easy, moderate and difficult galaxies belong to spiral, barred spiral and lenticular galaxies.

In the case of spiral galaxies in addition to easy, moderate and difficult designations, they exhibit a variety of views depending on their inclination to the solar system. Some will appear face on, others at a slight angle and a few completely edge on. They are symbolically represented as follows.

Face on :

Slight inclination :

Edge on :

The whirl pool galaxy is designated as easy. This galaxy is represented by

Messier 51 NGC 5194 8.4m [13.1m] SA(s) easy.

All the informations regarding the galaxy is contained in this line.

This one line representation says that the whirl pool galaxy occupies 51st position in the Messier catalogue and 5194th position in the new general catalogue. 8.4 m is the magnitude of the star and 13.1m is the surface magnitude of the galaxy. The symbol shows that is is a face on galaxy. SA(s) tells that it is an ordinary spiral galaxy. The word easy indicates that this comes under the designation easy.

This famous galaxy can be easily visible with binoculars. The galaxy appears as a small glowing patch of light with a bright star-like nucleus.

An example for moderate galaxy is

Messier 98 NGC 4192 10.1 m [13.2 m] SAB moderate.

This is a spherical barred galaxy (SAB) having magnitude 10.1 m and surface magnitude 13.2 m which is edge on. Since its designation is moderate it is difficult to locate. So a small telescope with aperture 10 cm is required.

Caldwell 26 NGC 4244 10.4 m [14 m] SA(s) difficult.

This galaxy, occupies 26th position in the Caldwell catalogue and 4244th position in the new general catalogue, having magnitude 10.4 and surface magnitude 14. It is an ordinary spiral galaxy and very difficult to locate or observe by binoculars. To observe this a telescope of aperture 20 cm is required.

Barred spiral galaxies

Here we give one example for each designation.

Caldwell 72	NGC 55	7.9 m [13.5 m]	SB(s) easy
Messier 109	NGC3992	9.8 m [13.3 m]	SB(rs) moderate
Messier 91	NGC 4548	10.1 m [13.3 m]	SB(rs) difficult.

Elliptical galaxies

Messier 84 NGC 4374 9.1 m [12.3m] E1 easy.

This galaxy is located close to Virgo cluster of galaxies. It appears as a small oval patch of light when seen through the binoculars. Sometimes the bright nuclei can also be glimpsed through the binoculars.

Messier 89 NGC 4552 9.7 m [12.3 m] E0 moderate.

It is a galaxy difficult to be seen with binoculars. If it is located by binoculars it appears as a small hazy spot. But with a telescope of medium magnification this elliptical galaxy can be seen. It appears as a bright and well defined nucleus enveloped by the mistiness of the halo.

Caldwell 35 NGC 4889 11.5 m [13.4 m] E4 difficult.

This galaxy is not possible to locate by binoculars. When viewing with a telescope of aperture 20 cm we can glimpse this as tiny object. This galaxy is a dominant member of the coma galaxy cluster which contains about 1000 galaxies. This is at a distance of 350 million light years.

Lenticular galaxies

Caldwell 53 NGC 3115 8.9 m [12.6m] SOsp easy.

This is a spindle galaxy. It is easy to locate this galaxy. With small binoculars it appears as a small faint elongated cloud but with large binoculars it will display its characteristic lens shape. With telescopes of aperture 20 cm it appears as a feature less oval cloud with slight brightening towards the centre.

Caldwell 57 NGC 6822 8.8 m [14.2m] IB(s) moderate.

It is called Bernard galaxy. Even though it is a fairly bright galaxy (8.8 m), its surface brightness is low [14.2 m] it is difficult to be seen through binoculars. If it is located it just appears as indistinct glow running from east to west. This is the bar of the galaxy. However a telescopes of aperture 10 cm it can be easily located. It may be noted that it is an irregular barred (IB) galaxy.

Active galaxies and Active Galactic Nuclei (AGN)

We classified galaxies earlier primarily on the basis of their shapes. But galaxies are different not only in their shapes but also in their physical properties. This time we are going to classify galaxies on the basis of their physical properties.

In galaxies usually most of the light energy is due to stars. The wavelengths of light emitted by stars depend upon their temperature in accordance with Wien's law ($\lambda_m T$ = constant). Stars with temperature greater than 40,000K and less than 3000K are very few in galaxies. So galaxies emit wavelengths in the region from infrared to ultraviolet. But some galaxies are found to emit radio waves, ultraviolet waves, X-rays and γ-rays. At the same time they emit incredible amount of energy. These galaxies are called active galaxies.

Energy source of active galaxies

We found that active galaxies emit high energy radiations. We cannot expect these radiations from stars alone. Then, where does it come from? So astronomers conjectured that these radiations are due to some other physical phenomenon occurring in galaxies.

According to the present knowledge, we believe that it is due to the presence of supermassive blackholes in the galaxies. A galaxy hosting a blackhole emits enormous amount of energy. This is possible only due to the phenomenon of accretion. **The heavy gravity pull of supermassive blackhole attracts materials such as gas, dust and other stellar debris into it. The materials come close to the blackhole, but not fall in to blackhole, forms a flattened band of spinning matter around the event horizon called accretion disc. This phenomenon of forming accretion disc is called accretion.** The interaction between the accretion disc and the blackhole results in the production of high energy rays depending on their temperature.

Now we can redefine active galaxy as follows. A galaxy hosting a blackhole provided with accretion disc emitting enormous amount of energy and radiations such as radio waves, u.v rays, X-rays and γ-rays.

It has been estimated that an active galaxy emits about 10 million times more radio energy than a normal galaxy. The amount of light given out by an active galaxy is about 100-1000 times more than a normal galaxy.

Active Galactic Nucleus (AGN)

The central region of any active galaxy is called active galactic nucleus. It is a compact region at the centre of galaxy that has a much higher luminosity than the other parts of galaxy. The spectrum given out by AGN indicates that the luminosity is not produced by stars. Such excess non-stellar emission has been observed in the radio, infrared, optical ultraviolet, X-ray, γ-ray wave bands.

A galaxy hosting an AGN is called active galaxy. The galaxy is active in the sense that AGN holds a blackhole with accretion disc and their interaction. Though our galaxy holding a blackhole, it is not active since it has no AGN and accretion disc.

The intensity of light emitted by acive galaxies are very high. Owing to this galaxies far away from milky way can be observed through radio telescopes. Even their galactic (AGN) centres can be observed. An ordinary galaxy at this distance cannot be seen even through telescopes.

The observed characteristics of an AGN depend on several properties such as the mass of the blackhole, the rate of accumulation of accretion disc, the orientation of accretion disc, the degree of obscuration of the nucleus by dust particles.

Based on the observed characteristics of AGN, they are classified into several. Some of them are given below.

(i) Seyfert galaxies types 1 and 2

(ii) Quasars

(iii) Radio galaxies

(iv) Starbursts galaxies

Seyfert galaxies

The story of the discovery of AGN began around the year 1943. In this year astronomer Carl seyfert published a paper in which he described observations of nearby galaxies having bright nuclei that have sources of emission lines. Galaxies observed as part of this study included NGC 1068, NGC 4151, NGC 3516 and NGC 7469. Active galaxies such as these are known as Seyfert galaxies in honour of Seyfert's pioneering work.

A galaxy which contains AGN is also called as host galaxy. Depending upon the shape host galaxy it is divided into two. They are seyfert galaxy and radio galaxy. Seyfert galaxies are spiral where as radio galaxies are elliptical.

Depending upon the nature of emission lines in the spectrum of AGN they are divided into seyfert 1 and seyfert 2 galaxies. If the spectrum contains 8 broad and narro emission lines they are called seyfert 1 galaxies.

If the spectrum contains only narrow emission lines they are called syfert 2 galaxies.

Quasars

The word quasar is the abbreviated form of quasi stellar radio sources. The name implies start like emitters of radiowaves. This name was given in the year 1960. The first quasar 3c273 was discovered by Maarten Schmidt at Halo observatories.

Quasar is a super luminous AGN at billions of light years away from us. All quasars emit X-rays in abundance. Only 5% quasars emit radio waves. Since quasars are far away from us they seen to be like stars when looking through telescopes. A quasar has mainly three parts 1) The central region (2) Jets and (3) Lobes. Jets emanating from the central region onto two sides and end up in lobes. The lobes are made of electrons moving with velocities about the velocity of light. When these electrons moving through the magnetic field they get accelerated and producing radio waves. This phenomenon is called as synchrotron radiation. It may be noted that quasars exhibit red shifts.

Definition of quasar

A quasar is an active galaxy whose AGN is extremely luminous in which there is a supermassive blackhole with mass ranging from millions to billions times the mass of the Sun surrounded by an accretion disc.

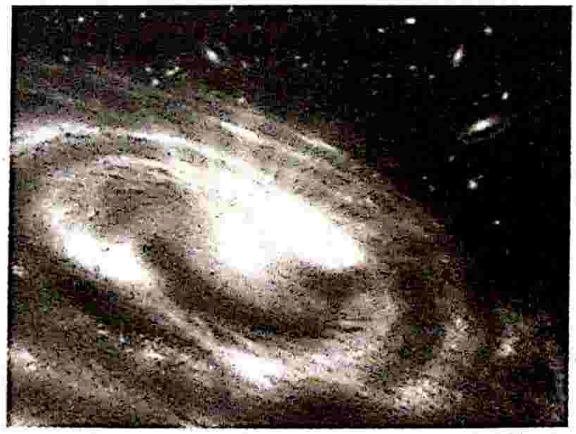

Figure 5.8: Quasar

Discovery of quasars changed our view of the universe.

1. Opened up study of the distant universe
2. Led to realise that super massive blackholes exist
3. Gravitational energy is the source for quasars and AGN

Radio galaxies

All quasars do not emit radio waves. Such quasars are called radio quite quasars. **Galaxies which emit radio waves are called radio galaxies.** This can be identified from the spectrum. Radio galaxies are spiral galaxies. Cygnus A and Centarus A are radio galaxies.

Star bursts galaxies

Star burst galaxies are galaxies formed when compared to others. For instance our Milky way galaxy converts gases of mass nearly $3M_{\odot}$ into stars in every year, whereas star bursts galaxies convert gases into stars about 100 times greater than by milky way. As a result the dust particles are much hotter and they emit infrared rays. Thus they are called ultra luminous infrared galaxy (ULIRG). Most of the star bursts galaxies are discovered by infrared astronomical satellites of NASA.

Gravitational lensing

In between a distant galaxy (light source) and an observer on earth massive objects (such as stars, blackholes and other galaxies) are distributed. **As light from the galaxy passes by these massive objects, the gravitational pull can bend the light rays. Here the matter between the galaxy and the observer acts like lens. This phenomenon is called gravitational lensing.**

According to Einsteins general theory of relativity, gravity can effect light rays. Thus light rays coming from a distant galaxy or a quasar when passes close to another galaxy or a blackhole, light rays get deviated from their path. This leads to different interesting effects.

1. When we observe a distant galaxy source we get two images of the source one is the direct image the other one is image produced by gravitational lens.

   This possibility was firstly predicted by Fritz Zwicky in the year 1937. In 1979 Dennis Walsh, Bob Carswell and Ray Weyman discovered a binary quasar named 0957 + 561. When they analysed their spectra and red shift they were found to be the same. The only difference is in their image positions. They were actually proving the phenomenon of gravitational lensing indirectly. That is 0957 + 561 is not a binary but a single one.

2. If the object behaving like a lens is very big and massive, for example galaxy cluster, its produces several images of the distant galaxy on a ring. This is called Einstein ring. Several such rings were observed when a distant blue galaxy was photographed by Hubble telescope.

3. If the mass of the object (lens) lying in the path of the light rays is small and heavy (blackhole), the lens focuses faint rays making it brighter. This is called micro lensing. Since the lensing process increases the brightness of light rays gravitational lens is also called as gravitational telescope.

All gravitational lenses discovered so far are incidentally. Gravitational lensing is used to probe the distribution of matter in the galaxies and clusters of galaxies. This enables us to observe the distant universe.

Now a days astronomers are searching for gravitational lenses to gather more informations about the cosmos.

Hubble's law

Hubble's law is one of the most important concepts in astrophysics. During the early part of the 20th century Edwin Hubble began to take the spectra of distant galaxies. Analysing the spectra he could understand that all galaxies exhibit red shift. Red shift is the phenomenon of shifting the spectral lines towards the red end of the spectrum. This indicates that galaxies are moving away from us. By observing large number of galaxies he arrived at Hubble's law. It states that the recessional velocity (v) of a galaxy is directly proportional to its distance (d)

i.e. $$v \propto d$$

or $$v = H_0 d$$

Where H_0 is called Hubble constant. the value of H_0 is found to be $70 kms^{-1}(Mpc)^{-1}$ (present value)

The red shift and the recessional velocity can be determined experimentally easily. this enabled us to know more about the cosmos and big-bang.

Note: The red shift (z) is given by

$$z = \frac{\lambda_{obsrved} - \lambda_{rest}}{\lambda_{rest}}$$

The red shift and Hubble's law we already dealt with in detail.

Clusters of galaxies

Most of the galaxies are found in clusters and single galaxies are very rare. If the cluster contains a few galaxies called small clusters and if it contains thousands of galaxies they are called giant clusters.

Small clusters occupy a region of space spread over only 1Mpc where as giant clusters occupy a region of space spread over about 10 Mpc.

The Milky way galaxy is a member of a small cluster called the local group containing more than three dozen other galaxies. There is another type of classification.

Clusters can be divided into two types. They are rich clusters and poor clusters. The rich cluster consists of more than 1000 galaxies and cover an area about 3Mpc in diameter. In this cluster galaxies are concentrated at the centre of cluster. At the centre there may one or two giant elliptical galaxies. For example Virgo cluster is a rich cluster with the giant elliptical M87 at its centre.

Poor clusters contain fewer than a 1000 members and as big as a rich cluster.

It is observed that rich clusters contain about 80-90% E type and 10% S0 type galaxies. Whereas poor clusters contain large proportion of spiral galaxies. The galaxies in isolation (those not in clusters) 80-90% are spiral galaxies. Observations of elliptical galaxies indicate that they are formed due to merging of spiral galaxies.

The evolution of galaxies is still not fully understood yet. However in clusters of galaxies collisions, merges and close encounters can obviously cause bursts of star formation and dramatic tidal disruption. It is due to this changes in clusters astronomers now believe that our Milky way is gradually swallowing Large magallenic cloud galaxy which is next to Andromeda galaxy.

UNIVERSITY MODEL QUESTIONS

Section A

(*Answer questions in about* **two** *or* **three** *sentences*)

Short answer type questions

1. What is a galaxy?
2. Give the names of any four galaxies.
3. Classify galaxies on the basis of their shape.
4. What is a spiral galaxy?
5. What is an elliptical galaxy?
6. What are irregular galaxies?
7. What are barred spiral galaxies?
8. What are lenticular galaxies?
9. Distinguish between spiral and elliptical galaxies.
10. The age of the stars in spiral galaxies are relatively younger. Justify.
11. What is meant by population I stars?
12. What is meant by population II stars?
13. What are the two essential conditions to observe galaxies with naked eye?
14. What are the designations given to galaxies that can be observed by a binocular?
15. When the galaxy is designated as easy?
16. When the galaxy is designated as moderate?
17. When the galaxy is designated as difficult?
18. What does the representation "Messier 81 NGC 3031 6.9m (13m) ʂ•ʂ. SA Easy" Mean?
19. A galaxy which is difficult to observe by binoculars occupying 48th position in the Caldwell catalogue and 2775 position in new general catalogue having magnitude 10 and surface magnitude 13.1, which is face on and ordinary spiral. Represent this galaxy?

20. What are active galaxies?
21. What is an active galactic nucleus ?
22. What is an accretion disc?
23. Define the phenomenon of accretion.
24. What all factors on which characteristics of an AGN depend?
25. Give the names of three active galaxies.
26. What is a seyfert galaxy?
27. What is a quasar?
28. Which are the three main parts of a quasar?
29. What are radio galaxies?
30. What are star bursts galaxies?
31. What is a gravitational lens?
32. What is gravitational lensing?
33. What is meant by red shift?
34. What is Hubble's law?
35. What is meant by clusters of galaxies?

Section B

(*Answer questions in a* **paragraph** *of about half a page to one page*)

Paragraph / Problem type questions

1. What is the structure of spiral galaxy?
2. Distinguish between population I and II stars.
3. What is Hubble classification of galaxies?
4. Distinguish between easy, moderate and difficult designation of galaxies.
5. Give a brief account of three astronomical catalogues.
6. How does an active galaxy get extra energy?
7. What are the effects of gravitational lensing?
8. Distinguish between a rich cluster and a poor cluster.
9. How does red shift and Hubble's law are related?
10. How did quasars discovery change our view of the universe?

Section C

(*Answer questions in about* **One** to **two** *pages*)

Long answer type questions (Essays)

1. Discuss galaxies in detail.
   (Definition, types and structure)
2. Discuss gravitational lensing in detail.
   (Definition, their effects and binary quasar)